Technological Forecasting and Social Change

An International Journal

Volume 49, Number 3, July 1995

Contents

ALAN L. PORTER (Atlanta, GA) and MICHAEL J. DETAMPEL (Green Bay, WI)	Technology Opportunities Analysis	237
NAMWOON KIM (Hong Kong, UK) VIJAY MAHAJAN and RAJENDRA K. SRIVASTAVA (Austin, TX)	Determining the Going Market Value of a Business in an Emerging Information Technology Industry: The Case of the Cellular Communications Industry	257
MARK W. SPEECE (Bangkok, Thailand) and DOUGLAS L. MACLACHLAN (Seattle, WA)	Application of a Multi-Generation Diffusion Model to Milk Container Technology	281
MARK E. DOMS (Washington, DC) and TIMOTHY DUNNE (Norman, OK)	Energy Intensity, Electricity Consumption, and Advanced Manufacturing-Technology Usage	297
JAMES P. GANDER (Salt Lake City, UT)	Academic Research and Teaching Productivities: A Case Study	311

Columns

JOSEPH F. COATES (Washington, DC)	*From My Perspective* Technology Assessment: Here Today, Gone Tomorrow	321
TOM MANDEL ET AL. (Mountain View, CA)	*From My Perspective* Tom Mandel and Friends: A Death On-Line Shows a Cyberspace with Heart and Soul	325

Book Reviews

HAROLD A. LINSTONE (Lake Oswego, OR)	*Research with a View to Implementation* and *Case Studies in Research with a View to Implementation* (D.J. Gouws)	329
HAROLD A. LINSTONE (Lake Oswego, OR)	*Predicting the Future* (Leo Howe and Alan Wain, Eds.)	331
	Announcements	334
	Erratum	335
	Volume 49 Author Index	336
	Volume 49 Book Index	336
	Volume 49 Subject Index	337
	Volume 49 Contents	

NORTH-HOLLAND

Determining the Going Market Value of a Business in an Emerging Information Technology Industry: The Case of the Cellular Communications Industry

NAMWOON KIM, VIJAY MAHAJAN, and RAJENDRA K. SRIVASTAVA

ABSTRACT

Given the phenomenal growth or the anticipation of growth in certain information technology industries, concerns for economy of scale, market access and expansion, and the need for ongoing research and development are resulting in mergers, acquisitions, and strategic alliances. A key question in such industries is what is, or should be the going market value of a business? This paper suggests an approach to imbed market penetration models in the popular value-based planning approach suggested by Rappaport [36] to obtain the going market value of a business. The model developed in implementing the approach is tailored for the cellular communications industry. Limitations and adaptations of the approach to other industries are discussed.

Introduction

Breakthroughs in information technologies in the last two decades have dramatically transformed world culture and facilitated the birth of the information age [37]. These technologies are influencing business operations, the quality of our work life and the quality of home life [16, 22, 28, 35]. More than 50% of the U.S. labor force is involved in the "information" sector today, and this sector of the economy is outpacing every other sector, including the service sector [5]. Information technologies are revolutionizing the current industries (e.g., airline industry), initiating new industries of the future (e.g., cellular communications) [43] and are expected to have major impact on businesses [4]. With the implementation of ISDN (Integrated Services Digital Network) and development

NAMWOON KIM is Assistant Professor of Marketing, Hong Kong University of Science and Technology.
VIJAY MAHAJAN is the John P. Harbin Centennial Chair Professor of Business Administration.
RAJENDRA K. SRIVASTAVA is the Sam Barshop Professor of Marketing and the Charles A. LeMaistre Centennial Fellow at the IC² Institute, The University of Texas at Austin.
Address reprint requests to Rajendra K. Srivastava, Chair and Sam Barshop Professor of Marketing, Department of Marketing, CBA 7.202, University of Texas at Austin, Austin, TX 78712-1176.

The authors would like to thank Professor Jerry Wind of the Wharton School, University of Pennsylvania for suggesting this problem. The research was supported in part by the IC² Institute, The University of Texas at Austin.

All opinions expressed are those of the authors who share equally in contributions and remaining errors. Comments are welcomed.

Technological Forecasting and Social Change 49, 257–279 (1995)

655 Avenue of the Americas, New York, NY 10010
0040-1625/95/$9.50
SSDI 0040-1625(95)00012-Y

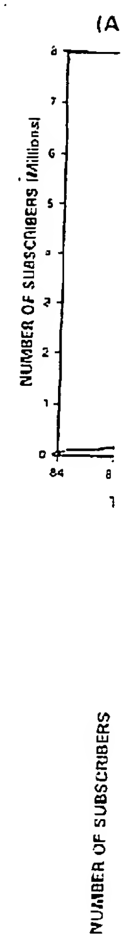
of multimedia applications of computer technology, the markets for computer and telecommunications companies are converging, signaling potential for further growth [17].

Given the phenomenal growth or the anticipation of growth in certain information technology industries, concerns for economy of scale, market access and expansion, and the need for ongoing research and development are resulting in mergers and acquisitions and strategic alliances [21]. A key question in such industries is what is or should be the going market value of a business?

Consider, for example, the cellular communications industry. Although mobile telephone systems have existed since the 1940s, they did not achieve widespread acceptance due to the limited number of channels available to users. In 1958 Bell Labs discovered a new system that allowed for "frequency reuse" and "cell splitting," meaning that the same frequencies could be used over and over again, thereby increasing the capacity severalfold [7]. This new technique formed the foundation for cellular telephone systems as they exist today. These systems, however, were inaugurated in 1983 after a lengthy application and licensing process conducted by the Federal Communications Commission (FCC). From the 1200 applications originally filed, the FCC licensed two competitors, one wireline and one nonwireline, in each MSA (metropolitan statistical area) and RSA (rural service area). Almost immediately after the licenses were granted, the license holders began to trade and sell their licenses, resulting in the consolidation that the industry has been experiencing ever since [7]. Because of these acquisitions, some of the major players in this industry now include McCaw, GTE, PacTel, Bellsouth, and Southwestern Bell. For several years, many of the original and consolidated companies experienced annual growth rates of well over 100%. But, recently, the annual growth rate has slowed down to around 30%–60%. Overall, although so far only 3% of the U.S. population has adopted cellular phones, this figure is expected to reach double digits and generate $30 billion annually by the end of this century. Figure 1A depicts the accelerated growth in terms of number of subscribers achieved by this industry [7, 8, 9, 11, 20].

Figure 1B shows the price paid by the various acquirers in this industry from 1984 to 1991. The vertical axis in this figure reports price per "pop," the most common valuation measure of a cellular company used in industry. *This measure reflects what a franchise is worth when divided by the number of people living in the served area.* Pop For example, in June 1990 *Fortune* reported that although price per pop value varies regionally (earnings per subscriber depend on pricing and usage rates, which can be expected to depend on population characteristics and urban/rural mix), the estimated going price per pop based on recent acquisitions at that time was about $200. Hence, since the Atlanta-based Contel was serving 90% of the 22.3 million people in its marketing area, its cellular operations should have been worth about $4 billion [20]. In fact, Contel was acquired by GTE in March 1991 for $6.7 billion [21]. Note in Figure 1B that price per pop in the cellular phone industry increased from $6 in 1984 to $302 in 1991.

From Figures 1A and 1B we see that a strong relationship exists between the market penetration and the market value of a business. Supporting this logic, the overlay of Figures 1A and 1B in Figure 1C, suggests that the trend in the number of subscribers is mirrored by the trend in the price per pop. That is, as potential subscribers are converted into actual subscribers, the value of the business increases. Of course, there lies uncertainty in *both* the conversion rate and the ultimate market penetration. Hence, given these trends in Figure 1, several questions emerge: Will the growth trend for the price per pop continue forever? Will price per pop level off? Is there a systematic model that one can use to describe, estimate, and project long-run market value of a business (price per pop) over time?



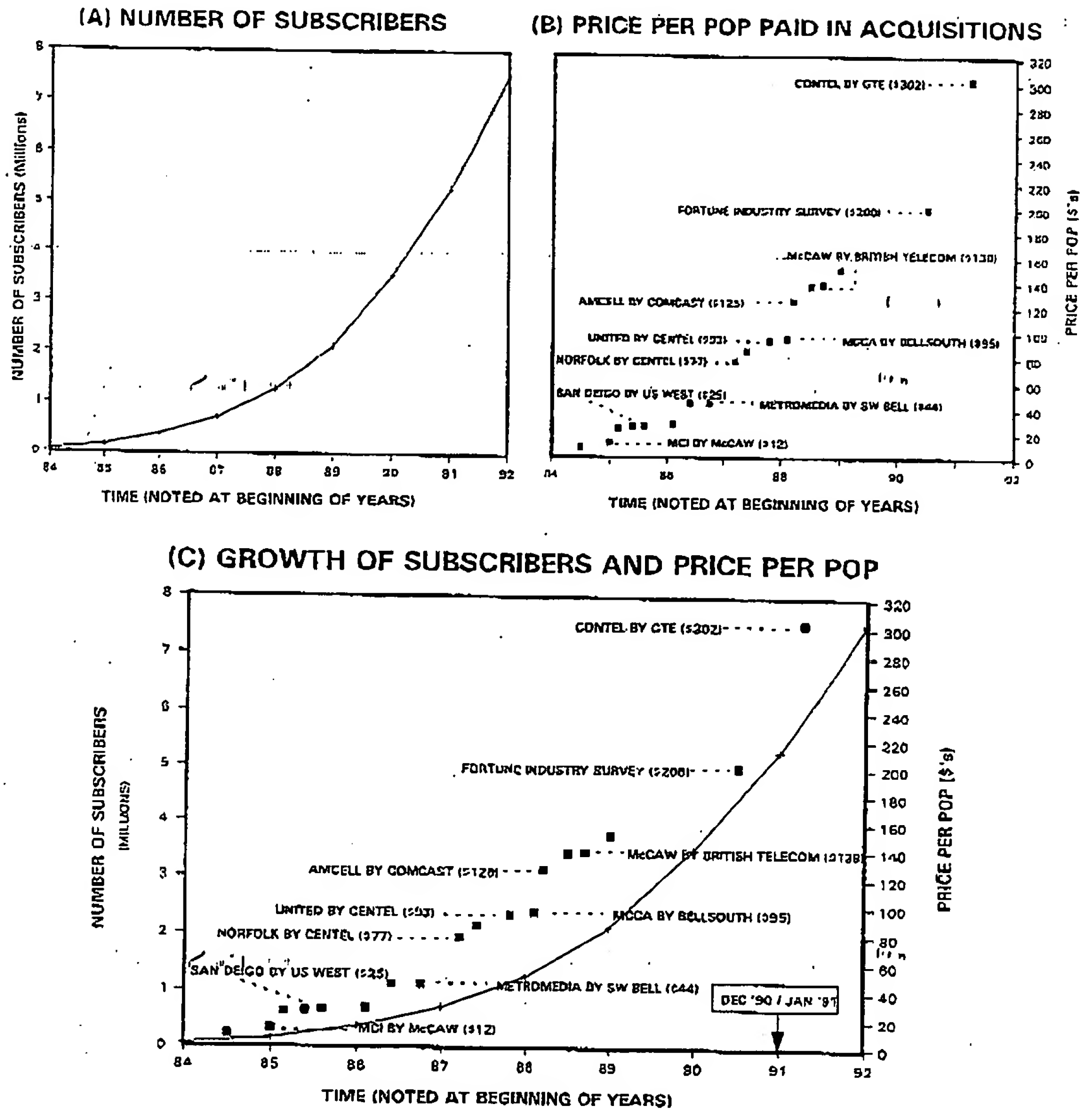


Fig. 1. Market penetration and market value patterns in the cellular telecommunications industry.

This paper is concerned with these questions. Toward this end, the objective of this paper is to suggest a model that can be used to study the market value dynamics over time. The proposed model builds on the components of market value (e.g., cash flows and projected revenues, cost and investments) to develop a long-run dynamic model of market value. Such a model can make long-run value projections and is therefore more useful to potential entrants and investors compared to the simpler regression/econometric approaches that might be used to make 1-year-ahead forecasts. Because the price per pop value varies regionally, the model is not designed to provide a unique value for a particular cellular firm. Rather, it provides the "going" value in the industry. This value provides a benchmark value that needs to be adjusted for regional market differences. The proposed model has the following distinguishing features: (1) it provides a systematic way to examine the relationship between market penetration, cash flows, and market value of a business in the long-run as well as in the short-run, (2) it explicitly considers

new venture risk dynamics, in terms of cost of capital, in assessing market value of a business, and (3) in evaluating market penetration, it uses the well-established diffusion models in marketing to describe cellular phone growth over time.

It should be pointed out here that although the model is developed for the cellular communications industry due to data availability considerations, it can be extended and adapted to other information technology industries. Possible applications to other industries are discussed in the conclusion section of the paper.

The remainder of the paper is organized as follows. The following section briefly presents a popular market valuation approach suggested by Rappaport [36] and identifies the linkage between market penetration and market value of a business. Then, based on this linkage, we develop a market valuation model for the cellular communications industry and investigate sensitivity of the projected market values to the two important decision variables, cost of capital, and value growth durations. Practical implementation issues and implications of the model for the industry are also discussed. Finally, this paper concludes with limitations and adaptation of the proposed approach for other industries.

Relationship between Market Penetration and Market Value of a Business: The Market Value Approach

How should one determine the market value of a business? Although several approaches have been suggested and evaluated in the financial management and strategic market planning literature to assess the value of a business (for a comparison of such approaches [see 29, chp. 9], a popular value-based planning approach has been proposed by Rappaport and the Alcar Group, Inc. [3, 36]. This approach is based on discounted cash flow analysis. The discounted cash flow model estimates the economic return from an investment by discounting forecasted cash flows by the cost of capital for the business. These cash flows in turn serve as the foundation for shareholder returns from dividends and stock share-price appreciations [1, 13, 36].

Value-based planning approaches are becoming increasingly important in strategic decision making for purposes such as allocation of resources among options that offer growth but are inherently risky [6]. The importance of such approaches is underscored by the fact that a large proportion of the value of firms is based on their perceived growth potential and associated risks [33, 44]. That value is based on expectations of future performance. More specifically, the value-based planning approach proposed by Rappaport suggests that seven factors or "value drivers" affect the market value of a business. They are (1) rate of sales growth, (2) operating profit margin, (3) income tax rate, (4) investment in working capital, (5) fixed capital investment, (6) cost of capital, and (7) value growth duration. The last factor, value growth duration, represents management's estimate of the number of years that the business can maintain its competitive superiority to produce profitability levels higher than the cost of capital. After the value-growth duration, profitability regresses to the cost of capital (which implies that the market value of the remaining or residual cash flow is equal to the book value of the firm's investments).

Once the information on these seven drivers is assembled, the market value at time $\overline{T}$, $\pi(\overline{T})$ [note that $\overline{T}$ in text is same as $\bar{T}$ in figures], which is composed of (a) present value of cash flows during the value growth duration ($\pi_1(\overline{T})$) and (b) present value of the residual value ($\pi_2(\overline{T})$) is given by:

$$\pi(\overline{T}) = \pi_1(\overline{T}) + \pi_2(\overline{T}) = \sum_{t=\overline{T}}^{T} \frac{CF_t}{(1 + K_{\overline{T}})^t} + \frac{RV_T}{(1 + K_{\overline{T}})^{T-\overline{T}}} \qquad (1)$$

where CF_t = cash flow at time t;

$K_{\overline{T}}$ = risk-adjusted cost of capital at time $\overline{T}$, the time the valuation begins;
$T = \overline{T} + T^*$ where T^* is value growth duration period;
RV_T = residual value at the end of the value growth duration, (i.e., at T).

The valuation model given by equation (1) is deceptively simple. Its implementation presents problems because the choice of the appropriate risk-adjusted cost of capital, estimates of the residual value, and the difficulty in obtaining reasonable forecasts of future cash flows represent daunting hurdles [14]. All too often, simplistic assumptions (for example, 5% annual growth) are implemented in projecting cash flows over arbitrary value growth duration (typically, 5 to 7 years). Such convenient assumptions are potentially troublesome. First, the rate of growth is rarely constant. It depends on the stage of the product life cycle and demand/supply dynamics. Second, a value growth duration of (say) 5 years may exclude periods with substantial growth potential when implementing the shareholder value model early in product life cycles because the time to peak sales is rarely less than 10 years for consumer durables as well as business products and services. Clearly, a nonlinear model capable of capturing both growth of sales and market saturation can provide superior estimates and diagnostics compared to simplistic models. life cycle

Additionally, high values of risk-adjusted cost of capital can lead to undervaluing of future events/outcomes because traditional discounting methods provide a geometrically decreasing sequence of weights [25]. Harvey and others [30, 41] note that decision makers often exhibit decreasing risk aversion over time, especially for pay offs in the distant future. It might also be reasonable to expect that both the level and nature of risks (e.g., market size and market share uncertainty) decrease over the product life cycle [32]. Further, as standards emerge and are implemented in the marketplace (e.g., adoption of ISDN in telecommunications), risks to both adopters of technology and to investors in a company marketing a technological innovation decrease. This suggests that the cost of capital can be expected to decrease sequentially over time and should prove to be more useful compared to a constant (and high) cost of capital scenario.

We believe that new product diffusion models or market penetration models can assist in improving cash flow projections over the value growth duration. Such a notion has also been endorsed by Gilman [23] and House and Price [27]. Further, in contrast to traditional discounted cash flow approaches, we allow the cost of capital to change over time as market uncertainty and risks change. This flexibility allows for reducing the potential of undervaluing future outcomes (cash flows). These unique modeling features (using market growth models to project cash flows and flexible discounting to determine present value of these future cash flows) can be applied to most emerging industries. We demonstrate our modeling approach (summarized in Figure 2) in the next section by estimating the price per pop in the cellular telecommunications industry. Revenues and cash flows in service operations, as summarized in Figure 2, are driven largely by the total number of customers (i.e., cumulative adoptions). But, valuation of businesses marketing hardware (e.g., cellular telephones) is likely to be more dependent on new adoptions (i.e., sales, not cumulative sales).

Valuation Model for the Cellular Communications Industry

Given the discussion in the preceding section on the value-based approach, the question now is how this approach can be used to assess the going market value of a business in the cellular industry. More specifically, how can we use this approach to assess the price per pop value over time (as given in Figure 1)? As mentioned earlier since this value

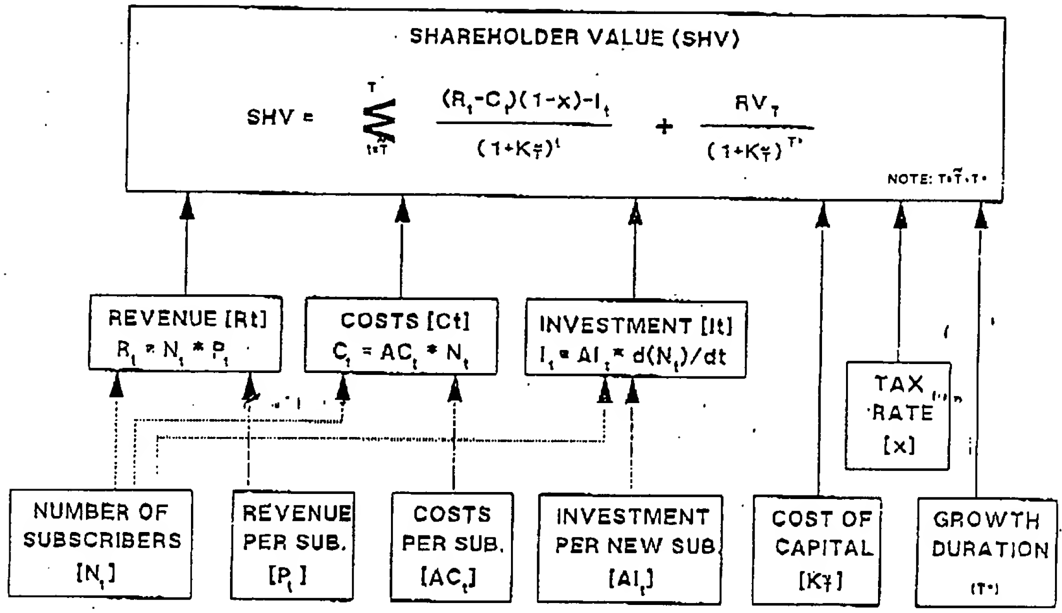


Fig. 2. Drivers of the valuation model ($\tilde{T}$ same as $\overline{T}$ in text).

can vary from market to market, to estimate the going or the benchmark value we assume that the entire cellular industry is a single business.[1] Using the industry-wide market penetration data (i.e., Figure 1A), we project the growth in cellular telephone subscribers. The information, coupled with estimates for revenues, costs, and investment per subscriber, is used to project cash flows. As illustrated in Figure 2, which summarizes the value components in the case of the cellular telecommunications service industry, revenues, costs, and investments are closely linked to the number of subscribers. As discussed in the next section, factors unrelated to the number of subscribers such as fixed costs and investments are less critical determinants of trends or changes in shareholder value. Finally, we estimate the market value for the entire industry by using equation (1) to discount the cash flows. This value when divided by the potential U.S. market for the cellular phones provides an estimate for price per pop. As we will demonstrate empirically shortly, this approach is effective in capturing the price per pop dynamics depicted in Figure 1. Per

IDENTIFICATION OF VALUE DRIVERS

Following the value drivers identified by Rappaport [36], Figure 2 summarizes the specific value drivers for the telecommunications industry. The functional form of these drivers and specification of appropriate parameters are summarized in Table 1 and discussed in greater detail in the next section. Figure 2 elaborates on the growth [$\pi_1(\overline{T})$] and residual [$\pi_2(\overline{T})$] value components of equation (1) for the cellular telecommunications industry. Cash flows during any period t (CF_t in equation 1) are given by the excess of revenues (R_t) over costs (C_t), which is adjusted by tax rate (x), minus investments (I_t). Clearly, the going market value will increase with an increase in cash flows [$= (R_t - C_t)(1 - x) - I_t$].

[1] Although one might adjust the model parameters to estimate the market value of a specific company in a specific geographical market and make additional adjustments to reflect specific strengths and weaknesses of the firm if such data were available, this is not the focus of this paper.

Market diffusion models can be very helpful in developing an understanding of how these value drivers (revenues, costs, and investments) will change over time because changes in all these variables can be linked to the growth in the number of subscribers. As summarized in Figure 2:

1. Revenues (R_t) can be captured by multiplying the number of subscribers (N_t) by the revenue (annual service charge or price) per subscriber (P_t). Note, value is created by increasing the combination of number of customers *and* prices.
2. Costs (C_t) can be represented by the product of the number of subscribers (N_t) and the average cost of providing service per subscriber (AC_t).
3. Net income ($R_t - C_t$) is adjusted by the tax rate (x) to get the net income after tax $[(R_t - C_t)(1 - x)]$.
4. Investments (I_t) are given by the incremental investment per *new* subscriber (AI_t) multiplied by the number of new subscribers (i.e., the rate of change of subscribers dN_t/dt in Figure 2). A more detailed description of investments follows.

It is also important to understand the role of the cost of capital ($K_{\bar{T}}$ at the time $\bar{T}$ when value is being determined) and the value growth duration (i.e., the time period $\bar{T}$ to $\bar{T} + T^*$). A decrease in cost of capital (or discount rate) implies that future cash flows become more valuable. This is typically the case in new industries where market acceptance fears are alleviated and uncertainties (for example, regarding industry standards, product compatibility, market shares, margins, etc.) are resolved over time. Usually, this point is missed by managers when they evaluate product/business projects in early stages of an industry's life cycle and they are prone to apply high-risk premiums to the cost of capital [13].

Because valuation models assume that there is no growth in value after the value growth duration, appropriate specification of this period is critical. Too short a growth duration *undervalues* the potential by ignoring value generated by increases in cash flows (due to an increase in subscriber base) beyond the specific duration. This would especially be a problem in the early stages of an industry's life cycle because the typical S-shaped growth pattern implies minimal growth early in the diffusion process. For example, in telecommunication service industries, revenues and cash flows are generated across subscribers. Hence, if the value growth duration falls short of time when the subscriber base approaches saturation, it would result in underestimation of the residual value (RV_T in equation 1), which is given by:

$$RV_T = \frac{(R_T - C_T)(1 - x) - I_T}{K_{\bar{T}}} \tag{2}$$

where $K_{\bar{T}}$ is the cost of capital at the beginning of value growth duration (i.e., at time $\bar{T}$) and $(R_T - C_T)(1 - x) - I_T$ is the cash flow at the end of this period (i.e., at time $T = \bar{T} + T^*$). The residual value given by equation (2) may be recognized as the expression for the present value of an annuity, because it is assumed that cash flows at the end of the value growth duration will continue indefinitely.

Finally, the reader will note that we have incorporated the income tax rate as a value driver. In our subsequent analysis we use the *maximum* tax rates (46% through 1986, 34% thereafter) because the scale of operations for cellular firms is such that the income level beyond which the maximum tax rate kicks in ($100,000) is easily met. Any variation below the maximum tax rate would simply inflate after-tax cash flows proportionately.

and would not affect trends in value projections. Further, because of the discontinuity in tax rates, we can expect a "kink" in value projections around 1986–1987 (i.e., market value should increase due to a decrease in tax rates from 1986 to 1987). The analytical model and estimates for the value drivers in Figure 2 are summarized in Table 1 and discussed below.

FORMULATION AND ESTIMATION OF VALUE DRIVERS

Number of Subscribers (N_t)

Although the Bass [2] model is often used to capture growth in market penetration over time, we use the Logistic Internal Influence model [31] for the market penetration function. This model was used because: (1) it is more parsimonious than the Bass model, which incorporates both internal and external influences, (2) the coefficient of external influence (the "p" parameter in the Bass model) was not significantly different from zero, (3) the inflection point had not been reached (i.e., the rate of adoption is still increasing in the estimation sample) and hence an internal estimate of market size as specified by the Bass model could not be obtained, and, as we show subsequently, (4) it provides a good-fit with the data. This model, also called Technological Substitution Model [19], has the cumulative distribution function,

$$F(t) = \frac{1}{1 + e^{-(a + bt)}} \tag{3a}$$

which is obtained from the integration of the following differential equation that describes the change in rate of adoption over time:

$$\frac{dF(t)}{dt} = bF(t)(1 - F(t)) \tag{3b}$$

and $F(t = 0) = 0$.

In equations (3a) and (3b), a is a constant of integration, b the coefficients of imitation, and $F(t)$ is the proportion of cumulative adopters at time t. If M is the market potential, $MF(t)$ and $M\,dF(t)/dt$ represent cumulative and new subscribers, respectively. It is reasonable to use this functional form for the cellular telephone service industry adoptions because this functional form assumes that new subscribers are influenced mainly by demand interdependency [15]. That is, new subscribers are largely influenced by word-of-mouth communication with existing subscribers and the utility of the network system increases with the number of subscribers. The functional form, however, assumes that there is no repurchase/replacement (i.e., a user does not subscribe to more than one service line) or discontinuance and hence the number of existing subscribers at any time is equal to the sum of all previous subscribers.

As reported in Table 1, using data from January 1984 through January 1991 and externally estimated market size[2] M (= 37.5 million or 15% of the U.S. population (250 million) under current marketing and pricing policies), diffusion parameters a (= −5.246) and b (= 0.486) were obtained via nonlinear regression as recommended by Srinivasan and

[2] The external estimate of market size was provided by Bose (A. Bose, personal communication, March 10, 1992). It was based on consideration of both residential and business markets. This estimate is consistent with other projections (e.g., Greenberg and Lloyd, April 1991 estimate 12% penetration by the year 2000). The implementation of personal communication networks (PCNs), expected in the mid-90s, may further boost market size estimates.

TABLE 1
Analytics of Value Drivers (Cash Flow Components)

Analytical formulation	Parameter (Parameter)	Parameter (Definition)	Comments
1. Market penetration $N_t = \frac{M}{1 + e^{-(a + bt)}}$	$M = 37.5$ million	Market size (million subscribers	Market size specified externally based on industry expert and reports
	$a = -5.246$	Constant	Diffusion parameters (a and b) estimated from industry data through 1991
	$b = 0.486$	Coefficient of imitation	
2. Service revenue or price per subscriber $P_t = Pe^{-\alpha t}$	$P = \$1{,}334$	Initial price	Parameters P and α estimated from industry data through 1991
	$\alpha = 0.048$	Rate of decrease of price	
3. Average service cost per subscriber $AC_t = He^{-\beta t}$	$H = \$333$	Initial cost	Estimated to be approximately 25% of revenue per subscriber and assumed to decrease at the same rate (i.e., $\beta = \alpha$ based on industry reports
	$\beta = 0.048$	Rate of decrease of costs	
4. Investment per New Subscriber $AI_t = \gamma$	$\gamma = \$850$	Incremental investment per new subscriber	AI_t is assumed to largely consist of incremental working capital and marketing/sales expenses (the cost of incremental network capacity is negligible). These are estimated from industry data.
5. Cost of capital $K_T = Ke^{-\delta t} + K_{min}$	$K = 0.24$	Constant for risk-adjustment to cost of capital	High value of K is used to represent high initial industry risk reflected in the cost of capital.
	$K_{min} = 0.12$	Minimum cost of capital	K_{min} is assumed to be approximately equal to a risk-free rate of 8% plus a market risk premium of 4%.
	$\delta = 0.6$	Rate of decrease of cost of capital	δ is determined empirically from model fits to the data.

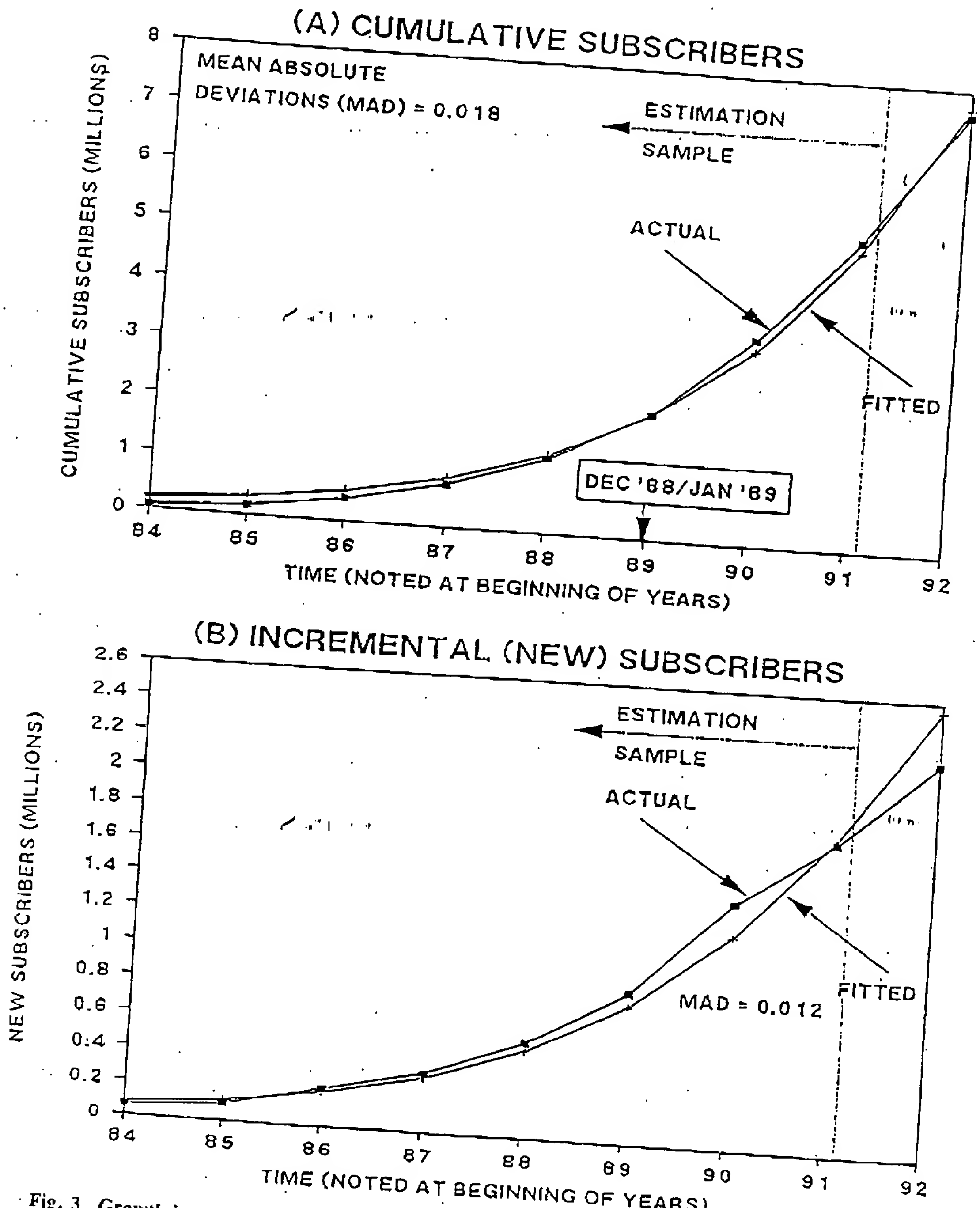


Fig. 3. Growth in subscribers for the cellular telecommunications service industry. (A) Cumulative subscribers. (B) Incremental (New) subscribers.

MARK

Maso
1989
betwe
mean.
R-squ

Reven
A
compa
per sub
(most
trying
the sub
be linke
telepho
Ex
custome
of subs
modeled

$P_t =$

where P
have dec
telephon
is the low
of appro
can be a
could no
because o
estimated
reports [2
P = $1,33
for 1992

Average
Custo
to network
the averag
we have:

$AC_t =$

where H a
crease, resp
Althou
the cost of
fixed costs
for usage-se
service reve
per year as
$333.5 for t

Mason [39]. The data were obtained from the *Chicago Tribune* [11], and supplemented for 1989 and 1990 from industry reports [9, 24]. Figure 3 shows the close correspondence between actual and estimated values for both cumulative (pseudo R-square = 0.998; mean absolute deviation = 0.018 million) and incremental (new) subscribers (pseudo R-square = 0.981; mean absolute deviation = 0.012 million) for annual periods.

Revenue Per Subscriber (P_t)

As shown in Figure 2, the majority of revenues generated by cellular telephone service companies is linked to monthly service charges paid by subscribers. The one-time revenue per subscriber generated from equipment sales is offset by the cost of cellular telephones (most cellular telephone companies do not make profits on equipment sales as they are trying to keep up-front adoption costs minimal for customers in their quest to expand the subscriber base). Thus although equipment prices have fallen rather sharply and can be linked to experience curve effects in manufacturing, they do not effect profits of cellular telephone companies and are accordingly not incorporated into the model.

Experience curve effects suggest that the cellular telephone service revenues (P_t) per customer can be expected to decrease exponentially with the increase in the number of subscribers over time [38]. Hence, cellular service revenues per subscriber could be modeled as:

$$P_t = Pe^{-\alpha t} \tag{4}$$

where P and α are constant coefficients, and t is time. Although fixed monthly charges have declined only marginally (on average less than 1%–2%) in the regulated cellular telephone service market [8], an additional source of decline in revenue per subscriber is the lower usage rate (minutes of connection time per month) leading to a net decrease of approximately 5% per year in the recent past [24]. This minimal decrease in prices can be attributed to the absence of strong experience effects in service industries. We could not estimate the separate effects of "fixed" charges and usage-sensitive revenues because only data on average revenues per subscriber were available. Equation 4, when estimated based on U.S. Department of Commerce [42] data through 1987 and industry reports [24] thereafter, yielded a revenue decay parameter of $\alpha = 0.048$ and initial revenue $P = \$1,334$ ($R^2 = 0.855$). Based on this relationship, projected revenues per subscriber for 1992 are approximately \$960 per year (or \$80 per month).

Average Service Cost Per Subscriber (AC_t)

Customer costs incurred for each subscriber are largely a function of activities related to network (e.g., installation) and account (e.g., billing) maintenance. If we assume that the average cost of subscriber decreases exponentially due to experience curve effects [12] we have: Cost sub

$$AC_t = He^{-\beta t} \tag{5}$$

where H and β are constants reflecting initial cost and the rate at which they decrease, respectively.

Although exact cost numbers are not available, industry reports [24] suggest that the cost of providing customer service is running at about \$10 per month for relatively fixed costs such as billing and customer service and \$0.05 per minute (×, 180 minutes) for usage-sensitive costs such as access. This translates into roughly 25% of the monthly service revenue of \$80 per subscriber, and can be expected to decrease at the same rate per year as revenue per subscriber (i.e., $\beta = \alpha$). Accordingly, we assume $H = 0.25P = \$333.5$ for the initial cost, and $\beta = \alpha = 0.048$.

Income Tax Rate (x)

As mentioned earlier, we assume federal income tax rates of 46% for 1984–1986 and 34% from 1987 until the present [18] because we model cash flows at the industry level. Of course, at the company level the tax treatment would depend on the specific circumstances of a firm. For simplicity we assume the maximum applicable tax rate in each year.

Average Investment Per Subscriber (AI_t)

Investment in the cellular telephone industry is primarily related to expansion of network capacity and geographical reach, incremental working capital, and marketing expenditures to recruit additional subscribers. Because network expansion, working capital increases, and marketing expenses for new customers can all be linked to the number of new subscribers [29, 40] the average incremental investment per new subscriber is given by:

$$AI_t = \gamma \tag{6}$$

where γ is a constant (i.e., investments $I_t = AI_t \times \frac{dN_t}{dt} = \gamma \times \frac{dN_t}{dt}$.

Due to technological advancements, the cost of incremental network capacity is minimal (it is our understanding that current capacity is in excess of demand). So γ largely consists of incremental working capital needs and marketing/sales costs—which are not expected to change unless the nature and intensity of competition change. Our analysis of data from the U.S. Department of Commerce (1988) [42] reveals it to be approximately \$800–\$900 of investment per new subscriber (i.e., γ in equation 6 is equal to 850). Although this number seems high, because cellular firms have been willing to pay high commissions to distributors and have often given away hardware (cellular phones) in exchange for contractual obligations, the reader will note that the amount can be recouped by cellular firms in the first year of service provision.

Cost of Capital (Discount Rate, K_t)

Although previous studies deal with constant discount rates for their profit analysis, we examine the effects of both constant and decreasing discount rates in our market valuation model. Under the later assumption, the cost of capital changes (decreases) as we go along the product life cycle. The reader should note, however, that at any one point in time, the cost of capital K_t used to discount future cash flows is constant. But the cost of capital is allowed to vary as the reference point changes. For example, as shown in Figure 5, the cost of capital decreases from 36% in January 1984 to 20% by mid-1985. At mid-1985, however, all future cash flows are discounted at 20%. This allows for conservative valuations early in the life cycle. A decreasing cost of capital assumption is reasonable as actual market risk declines over the product life cycle as uncertainties related to market size, market share, and competition intensity are mitigated with the passage of time. The assumption is also congruent with the observation that venture capital required early in the industry life cycle is expensive, often in excess of 50%. As firms establish themselves they are able to raise capital via equity and debt securities. The debt cost of capital is often the cheapest (approaching "prime"). Finally, a decreasing cost of capital is consistent with the notion of contingent risks as the risk of failure

decreases with the duration of existence of firms (G. S. Day, personal communication, 1991). Accordingly, we assume an exponential distribution for the discount rate $K_{\overline{T}}$ as:

$$K_{\overline{T}} = Ke^{-\delta\overline{T}} + K_{min} \tag{7}$$

where $K_{\overline{T}}$ is the discount rate at time $\overline{T}$ and K, K_{min}, and δ are constants. The parameter δ determines the rate at which the cost of capital declines from $(K + K_{min})$ to K_{min} (which can be interpreted as the industry's cost of long-term debt). The special case of where $\delta = 0$ results in a constant discount rate. These parameters are not based on the external data, as has been the case for parameters related to other value drivers discussed earlier. Rather, the form of $K_{\overline{T}}$ and estimate of value growth duration (T^*) are determined based on the sensitivity of projected market value to these drivers. We examine issues related to these parameters ($K_{\overline{T}}$ and T^*) after we develop the full model.

INTEGRATION OF VALUE DRIVERS ESTIMATES INTO THE VALUATION MODEL

Given the estimates of individual value drivers from the previous section, we derive a continuous version of the market valuation model (the discrete case is given by equation 1). The value $[\pi(\overline{T})]$ is composed of discounted cash flows during the value growth duration $[\pi_1(\overline{T})]$ and the discounted residual value $[\pi_2(\overline{T})]$. The projected value at each time period $\overline{T}$ is determined by discounting all future cash flow components back to the time $\overline{T}$ at the cost of capital $K_{\overline{T}}$. Based on the discussion in the previous section, revenues, costs, and investments (R_t, C_t, and I_t, respectively) are given by:

$$R_t = P_t \times N_t = Pe^{\alpha t} \times N_t \tag{8}$$

$$C_t = AC_t \times N_t = He^{-\beta t} \times N_t \tag{9}$$

$$I_t = AI_t \times \frac{dN_t}{dt} = \gamma \times \frac{dN_t}{dt}. \tag{10}$$

The estimates for P, H, α, β, and γ are summarized in Table 1.

These revenues, costs, and investments can be integrated to determine the value of cash flows during the growth duration (from $\overline{T}$ to $T = \overline{T} + T^*$) discounted to $\overline{T}[\pi_1(\overline{T})]$:

$$\begin{aligned}\pi_1(\overline{T}) &= \int_{\overline{T}}^{T}[(R_t - C_t)(1 - x) - I_t]e^{-K_{\overline{T}}(t-\overline{T})}\,dt \\ &= (1 - x)\int_{\overline{T}}^{T}[Pe^{-\alpha t} - He^{-\beta t}]N_t e^{-K_{\overline{T}}(t-\overline{T})}\,dt \\ &\quad - \int_{\overline{T}}^{T}\gamma\left(\frac{dN_t}{dt}\right)e^{-K_{\overline{T}}(t-\overline{T})}\,dt\end{aligned} \tag{11}$$

and the residual value discounted to time $\overline{T}[\pi_2(\overline{T})]$:

$$\pi_2(\overline{T}) = \frac{(R_T - C_T)(1 - x) - I_T}{K_{\overline{T}}}e^{-K_{\overline{T}}(T-\overline{T})} \tag{12}$$

where $T - \overline{T} = T^*$ (the value growth duration as defined in equations 1 and 2).

On substitution of the functional form of N_t (given by equation 3b), the integrals in equation (11) can be approximated to the second-order terms of Taylor series expansion about the time period $\overline{T}$. After algebraic manipulations (available to interested readers in an expanded working paper from the authors), solutions to equations (11) and (12) are given by:

$$
\begin{aligned}
\pi_1(\overline{T}) = {} & (1 - x)PM\frac{1}{1 + e^{-(a + b\overline{T})}}e^{-\alpha\overline{T}}T^{*} \\
& + \frac{(1 - x)PM[(-\alpha - K_{\overline{T}})(1 + e^{-(a + b\overline{T})}) + be^{-(a + b\overline{T})}]}{2[1 + e^{-(a + b\overline{T})}]^{2}} \\
& - (1 - x)HM\frac{1}{1 + e^{-(a + b\overline{T})}}e^{-\beta\overline{T}}T^{*} \\
& - \frac{(1 - x)HM[(-\beta - K_{\overline{T}})(1 + e^{-(a + b\overline{T})} + be^{-(a + b\overline{T})}]}{2[1 + e^{-(a + b\overline{T})}]^{2}}e^{-\beta\overline{T}}T^{*2} \\
& - \frac{\gamma Mbe^{-(a + b\overline{T})}}{[1 + e^{-(a + b\overline{T})}]^{2}}T^{*} \\
& - \left\{\frac{-\gamma Mbe^{-(a + b\overline{T})}[b + K_{\overline{T}}]}{2[1 + e^{-(a + b\overline{T})}]^{2}} + \frac{\gamma Mb^{2}e^{-2(a + b\overline{T})}}{[1 + e^{-(a + b\overline{T})}]^{3}}\right\}T^{*2}
\end{aligned}
\tag{13}
$$

and

$$
\pi_2(\overline{T}) = \frac{(1 - x)M(P_e^{-\alpha T} - He^{-\beta\overline{T}})}{[1 + e^{-(a + b\overline{T})}]K_{\overline{T}}}e^{-K_{\overline{T}}T} - \frac{\gamma Mbe^{-(a + b\overline{T})}}{K_{\overline{T}}[1 + e^{-(a + b\overline{T})}]^{2}}e^{-K_{\overline{T}}T}
\tag{14}
$$

Thus the valuation at any point in time ($\overline{T}$) is simply a function of model parameters. Under the decreasing cost of capital scenario, $K_{\overline{T}}$ decreases with time $\overline{T}$. Of course, under constant cost of capital assumptions, $K_{\overline{T}} = K$ for all $\overline{T}$.

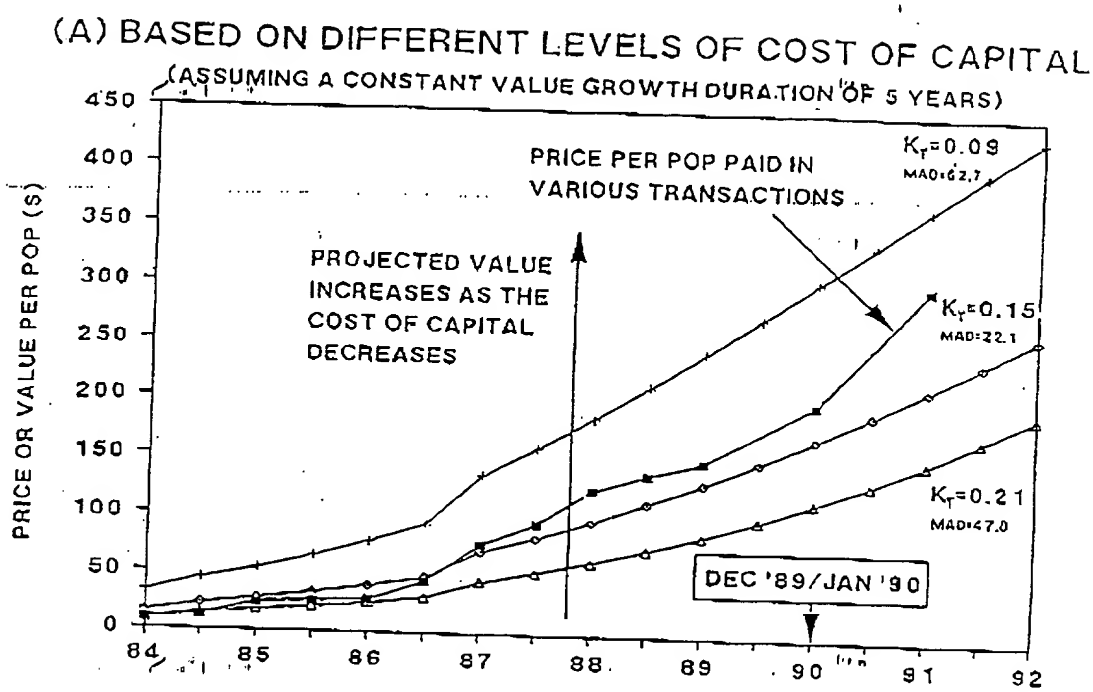
SENSITIVITY OF VALUE PROJECTIONS TO MODEL PARAMETERS

As can be seen from equations 13 and 14, projected values at each time period $\overline{T}$ are a function of researcher/manager supplied inputs such as the cost of capital ($K_{\overline{T}}$) and value growth duration (T^*), which affect the discounting process. Of course, value projections are also governed by estimates of model parameters (M, a, b), (P, α), (H, β), γ, and x, which determine market penetration, revenue, cost, investment per subscriber, and the tax rate. Because the latter (model parameters) are "known" (estimated) for the industry life cycle thus far, we first examine model fit by comparing actual price per pop paid in various mergers and acquisitions to the projected value per pop (obtained by dividing equations 13 and 14 by the U.S. population) based on different treatments of $K_{\overline{T}}$ and T^*. Subsequently, we examine the potential impact of changes in model parameters, most notably market potential (M) and rate of decrease of revenues per subscriber (α), on long-term trends in projected value per pop.

SENSITIVITY OF VALUATION OF BUSINESS TO COST OF CAPITAL AND VALUE GROWTH DURATIONS

To examine the sensitivity of valuation of business to various combinations of value growth durations and capital costs, we investigate the goodness of fit between projected market and actual values per pop under three scenarios: (a) fixed cost of capital (K) and various value growth durations (various T^*s), (b) fixed value growth duration (T^*) and various costs of capitals (various Ks), and (c) continuously changing cost of capitals ($K_{\overline{T}}$ as in equation 7) and various value growth durations (various T^*s).

Figure 4A shows that the projected value per pop increases with a decrease in cost of capital (value growth duration T^* is held constant at 5 years). Figure 4A also shows that there is closer correspondence between the projected value and actual price per pop at higher cost of capital ($K_{\overline{T}} = 0.21$) during the early years (1984 to 1986). In the mid-range years (1987 and 1988), this fit is higher for capital costs around 15%, shifting to a better



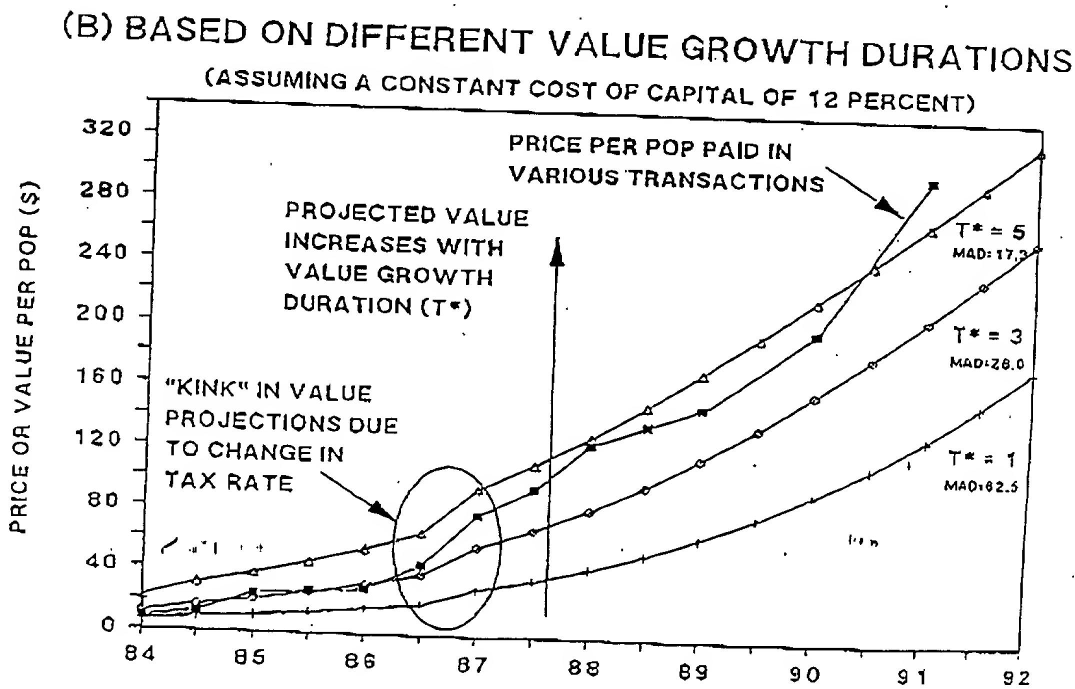


Fig. 4. Projected value patterns compared to price per pop paid in various transactions. (A) Based on different levels of cost of capital. (B) Based on different value growth durations (assuming a constant cost of capital of 12%).

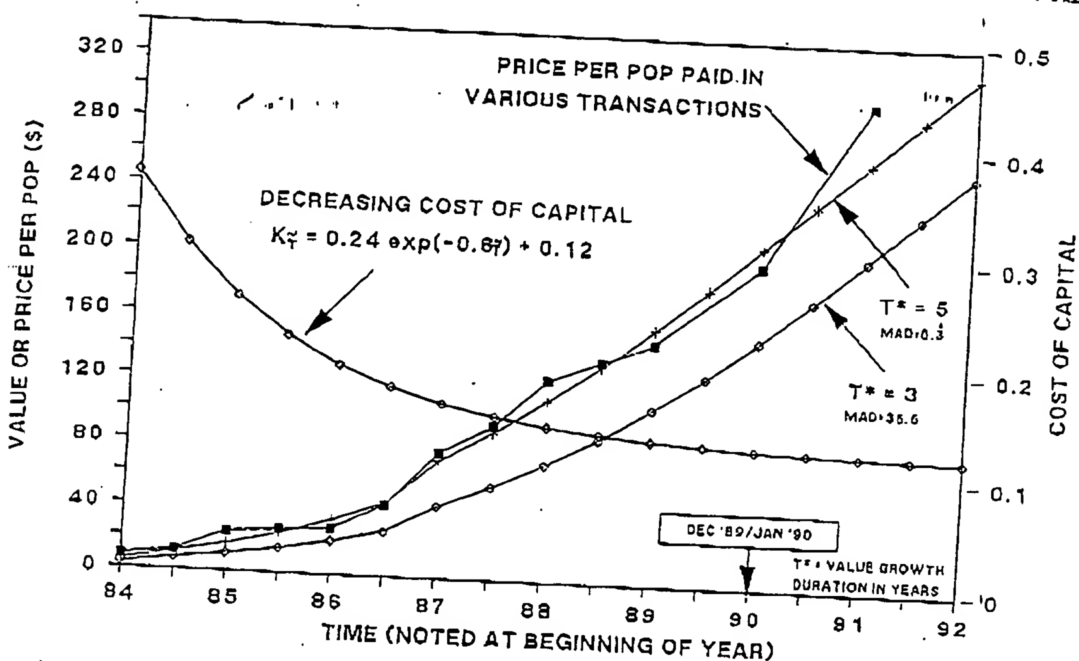


Fig. 5. **Price per pop compared to projected value patterns based on decreasing cost of capital and varying value growth durations ($\bar{T}$ same as $\overline{T}$ in text).**

fit at even lower costs of capital (less than 15%, but more than 9%) in the 1990s. This suggests that the cost of capital (and risk) applied by the market may decrease over time.

Figure 4B shows that projected value per pop increases with an increase in value growth durations (the cost of capital is held constant at $K = 0.12$). Again, actual price and projected value per pop can be compared. This comparison suggests that the market appears to be myopic (used shorter growth durations) early in the life cycle and gradually expands the value growth duration over the life cycle as more is learned about the industry and market uncertainties are resolved. Interestingly, as tax rates decrease from 46% to 34% after 1986, we observe a kink in value projections around 1987. This matches up with the increase in price per pop paid in various transactions during the same period. Note that it is not possible to separate the effects of decrease in cost of capital (Figure 4A) and increase in value growth durations (Figure 4B). Further, note that projections are based on market penetration models. Market expectations underlying actual price per pop may or may not conform to these projections. Investors may be prone to making straight-line, rather than nonlinear, extrapolations of market growth.

Integrating the effects illustrated in Figures 4A and 4B, we can examine the impact of continuously changing cost of capital (based on equations 13 and 14) and various value growth durations. Figure 5 shows the correspondence between projected value per pop and price per pop for two value growth durations (3 and 5 years). In each case, the same cost of capital scenario $K_{\bar{T}}$, decreases from 0.36 to 0.12 ($K_{\bar{T}} = 0.24e^{-0.6\bar{T}} + 0.12$). This cost of capital scenario was estimated heuristically in order to increase the fit between projected value and actual price per pop. Using high capital costs improves the fit between projected value per pop and price per pop substantially in the early stages of the life cycle. Additionally, the use of longer value growth durations improves the fit later in the life cycle. This can be expected because, as discussed previously, shorter value growth durations are prone to miss the growth in subscribers and hence underestimate residual values $[\pi_2(\overline{T})]$.

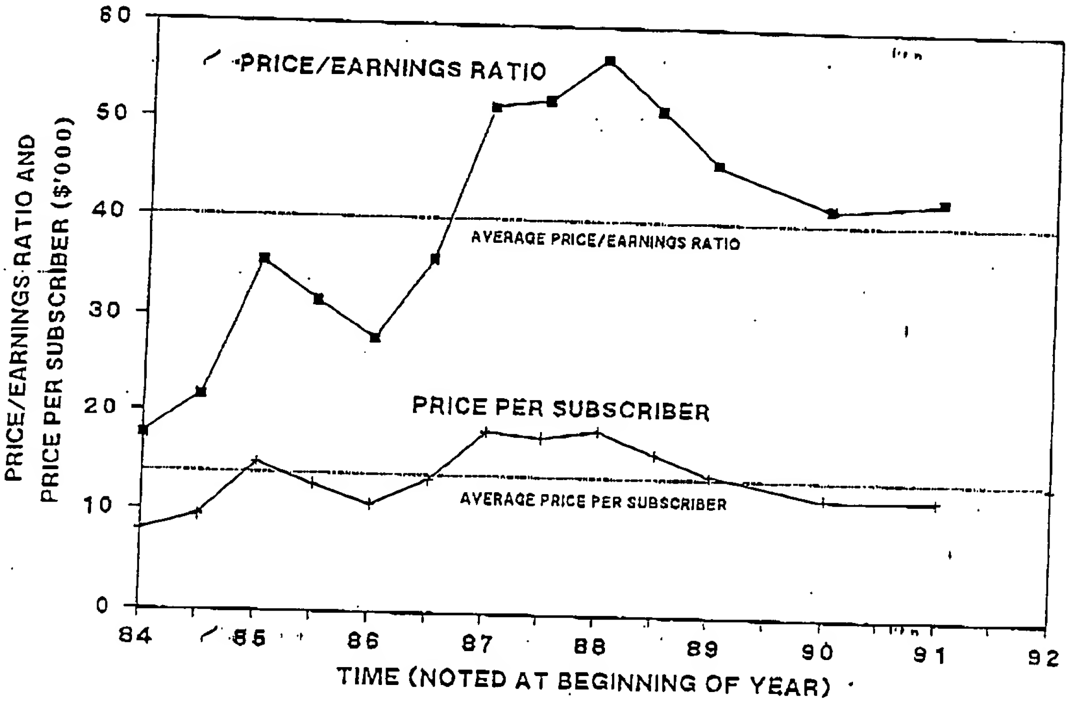


Fig. 6. Price/earnings ratio and price per subscriber for the cellular telecommunications service industry.

As a result, our model with a longer value growth duration ($T^* = 5$ years) provides a better fit between projected value per pop and actual price per pop (Figure 5, Mean Absolute Deviation = 8.3) compared to the more myopic model ($T^* = 3$) as well as other options in Figures 4A and 4B. Once again, one must note that cost of capital and value growth duration effects are confounded in the market with growth expectations. For example, one could increase the minimum cost of capital (0.12) late in the life cycle and simultaneously increase the value growth duration to achieve a similar degree of fit between projected value per pop and price per pop.

Although it is hard to separate the effects of $K_{\bar{T}}$ and T^* on value, examination of trends of other indicators of perceived value such as price/earnings (P/E) ratios and price per subscriber provide additional insights. These are plotted over time in Figure 6. P/E ratios for cellular telecommunications service firms grew from less than 20 to about 60 early in the industry's life cycle and have settled more recently at a level of approximately 40. By comparison, a "risk-less" government security paying 10% interest would have a P/E ratio of (1/.1 =) 10. Because P/E ratios reflect both potential for growth and risk, and increase of P/E ratios early in the life cycle could reflect both a reduction in perceived risks (hence capital costs) and a realization that the market was larger than previously anticipated. The current high P/E ratios of 40 suggest that the market perceives a large untapped market. Figure 6 also shows that the price per subscriber [= total market value of the business in U.S./number of subscribers = price per pop × (U.S. population/number of subscribers)] has historically varied in the range of $10,000 to $20,000 with an average price of $14,000 per subscriber. More recently, this price per subscriber has stabilized around $12,000. Hence as penetration increases, so does the total value of the company and therefore the price per pop. This appears to indicate that the companies

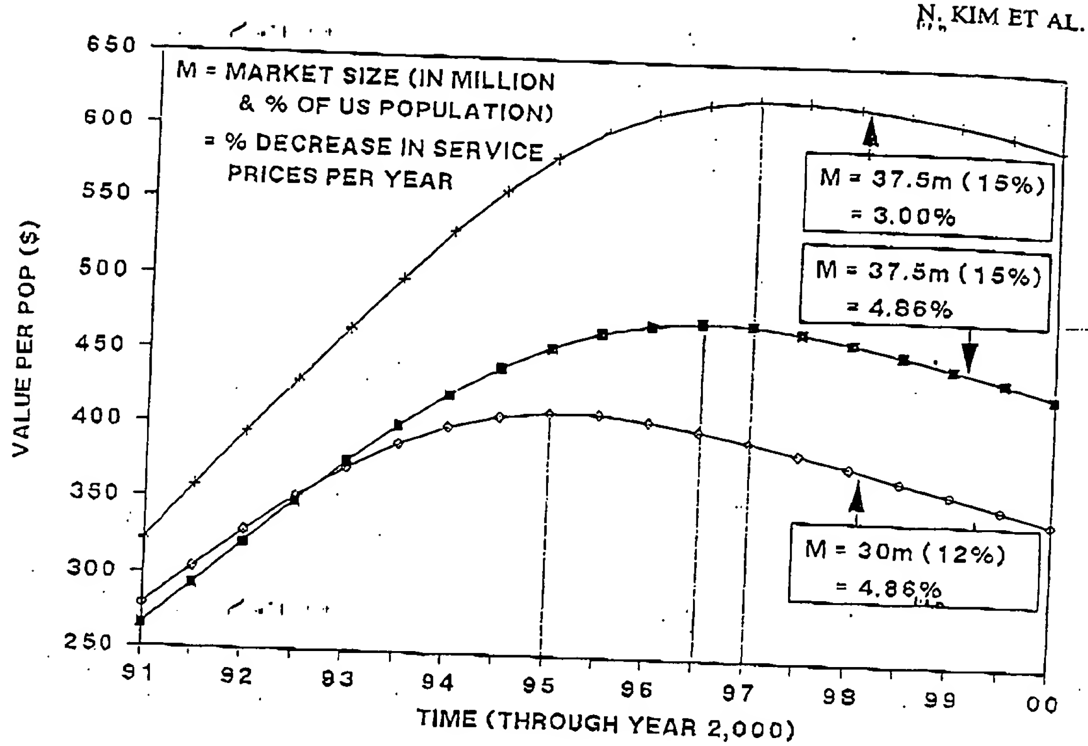


Fig. 7. Sensitivity of value per pop projections to market size estimates and service price trends.

concerned with mergers or acquisitions appear to be "reactive"—that is as market penetration increases, they tend to bid up the value of the business.

As is clearly illustrated by Figure 5, value per pop projections (and price per pop) are still increasing. When will the rate of growth in value decrease? What will be the saturation level of value per pop? These questions are examined next.

SENSITIVITY OF GROWTH IN VALUE PER POP TO MARKET SIZE AND REVENUE DECAY

In a previous section our analysis of growth in number of subscribers was based on an external specification of market size (M = 37.5 million, or 15% of the U.S. population of 250 million). This estimate may be optimistic given current technologies (Greenberg and Lloyd estimate 12%). New technological advances such as personal communications networks anticipated in the mid-1990s are expected to decrease the cost and, subsequently, the price of service. These may result in an upward revision of market size estimates [5]. Similarly, our analysis of changes in service revenues per subscriber revealed a revenue decay trend of 4.8% per year. This is at the high end of the 3%–5% range estimated by industry experts (24]. Because of uncertainties associated with these parameters (market size M and revenue decay α), it is imperative to examine their impact on growth trends in value projections. Although one might also focus on the change in costs, we assume that revenue per subscriber decreases parallel cost (and hence margin) declines (i.e., $\alpha = \beta$). Finally, the impact of γ (incremental investment per new subscriber) is expected to be minimal as the market saturates.

Figure 7 provides value per pop projections through the year 2000 under three scenarios: (1) our current "best" estimates for M (= 37.5 million, or 15% of the U.S. population) and α (= 4.86% per year decrease in revenues/margins), (2) a smaller market size M (= 30 million, or 12% of the population), but the same α (= 4.86%), and (3) a lower rate of revenue/margin decreases α (= 3 percent), but the same M (= 37.5 million).

Under the first scenario (M = 37.5 million/15%; α = 4.86), value projections grow steadily in the early 1990s. They peak in mid-1996 at about $480 per pop, and decline thereafter because growth in the number of subscribers is more than offset by continued decrease in revenues/margins. A similar pattern is observed under the second scenario (M = 30 million/12%; α = 4.86%). The reader will notice that the external specification of a smaller market size "forces" changes in estimation of diffusion parameters a and b so as to result in earlier market saturation, and correspondingly, an earlier peak (January 1995) in projected values (peak value = $410 per pop). Hence changing the externally specified market size does not cause more parallel shifts in value projections (i.e., both M and diffusion parameters a and b in equations 13 and 14 are affected).

Under the third scenario, the lower rate of decrease in revenues and margins (M = 37.5 million/15%; α = 3%) results in a much higher peak value per pop ($625) at the end of 1996. This much higher peak is due to the compounding effect of lower annual decrease in revenue per subscriber. Figure 7 provides several insights (e.g., sensitivity of market value to reduction in revenue per subscriber), which we examine in the next section.

Implications for the Cellular Communications Service Industry

Having helped the valuation model in the preceding section, the following questions can be addressed:

(1) Does the valuation model describe, estimate and project growth patterns in market value over time?

The penetration-based valuation model developed in this paper successfully captures the changes in value per pop during the estimation period (through January 1991). Changes in price per pop (from market transactions) match up quite well with projected value per pop based on growth in subscribers (which is accurately described by a new product diffusion model) and trends in revenue, costs, and investments per subscriber under a decreasing cost of capital scenario (Figure 5). Interestingly, model projections in Figure 7 suggest a price per pop range of $250 to $325 during the period from early 1991 through end 1992. Contel was acquired by GTE in March 1991 at $302 per pop. The Associated-McCaw deal was valued at $325 per pop in August 1992. And, in November 1992, AT&T acquired rights to purchase a one-third controlling interest in McCaw telecommunications at $271 per pop [8].

As noted, continuous increases in both subscribers and price per pop through 1991 indicate that the cellular telecommunications market is not saturated. Further, because the subscriber base is still growing at an increasing rate, the inflection point has not been reached. Unfortunately, this inflection point is necessary for internal estimation of market size [39]. In such a setting, an external estimate of market size is required [26]. Hence, although the proposed approach was quite adequate in capturing the pattern of value growth through 1991, its ability to perform through the rest of the 1990s depends on the accuracy of the external estimate of market size and other model parameters such as the rate of decay of revenues/margins (α). Although the value growth duration (T^*) was critical in earlier stages of the industry life cycle, value projections are less sensitive to T^* as growth levels off in later stages of the life cycle. Similarly, there should be less uncertainty regarding the cost of capital ($K_{\overline{T}}$) later in the life cycle because it can be estimated from historical information on security prices for firms in the industry using standard financial models (e.g., Capital Asset Pricing Model).

(2) How can the model be used for assessing the going market value of a business?

The total market value of a business at time $\overline{T}$ is specified by the sum of $\pi_1(\overline{T})$ and $\pi_2(\overline{T})$, which are specified by equations 13 and 14. In the previous section we demonstrated

how the going market value per pop (obtained by dividing the total market value by the U.S. population, i.e., 250 million) could be projected over time given estimates for model parameters ($M = 37.5$ million, $a = -5.246$, $b = 0.486$, $P = \$1,334$, $\alpha = 0.0486$, $H = \$333.5$, $\beta = \alpha = 0.0486$, $\gamma = \$850$ and $x = 0.34$) and an assumed values for the value growth duration ($T^* = 5$ years) and cost of capital ($K_T = 0.12$, the asymptotic value beyond 1991). Hence, for the middle of 1996 [($\overline{T} = 13.5$: $\overline{T}(1984) = 1$)] the going market value per pop can be computed at $480 (see Figure 7). This can then be multiplied by the product of the population covered by the business franchise in question and its market share to determine the going market rate.

Of course one may wish to adjust this value to reflect, for example, differentials in revenues, costs, and investments per subscriber from the national average due to varying demographics and competitive conditions as well as cost of capital. Also, as demonstrated in the previous section, one can perform "what if" analyses to examine, for example, the sensitivity of the going market value with respect to market size (eventual market potential) and revenue decreases.

(3) What insights can be inferred from this model for decision-making on mergers and acquisitions?

A variety of insights can be garnered from the valuation model (given by the sum of equations 13 and 14) when evaluating information technology businesses such as cellular telecommunications service firms. First, one can assess the sensitivity of values projected over time to model parameters. For example, Figure 7 demonstrates how one might graphically examine the trend in projected values and identify the peak value (and the timing of the peak), under varying assumptions of market size and decrease in average revenue per subscriber. We base these projections based on reasonable estimates of model parameters based on historical data that are likely to hold in the near future given current competitive practices. But, both parameters are likely to change if competition intensifies. Fortunately their movements are likely to have compensating effects on projected values. As competition increases, prices and hence revenue per subscriber can be expected to decrease. This loss can be offset by an increase in market size, however. Finally, uncertainty in market size can be expected to decrease once we observe an inflection point in the rate of adoption. Although equations 13 and 14 seem complicated, they can be easily incorporated on a spreadsheet. Of course, the same result can also be achieved by taking the derivative of the sum of equations 13 and 14 with respect to different model parameters, or with respect to time.

More specific insights for information technology businesses such as cellular telephone service firms that are based on sensitivity analyses, which were performed in the previous section include:

- The peak value per pop and its timing in the cellular depend on estimates of market size and the rate of decrease in prices (revenue) per subscriber. The projected value eventually decreases (beyond the peak) because the marginal increase in the number of subscribers is offset by the decrease in margins per subscriber. This typically occurs when the number of subscribers approach the market size.
- A reduction of market potential (size) estimate, given existing diffusion patterns implies that the value will peak both at a lower level (as expected) and earlier (not expected). This is because a larger estimate of the diffusion parameter "b" will be obtained given existing diffusion patterns and a smaller market size estimate (relative to a larger market size estimate).

- A lower rate of decrease in average revenue per subscriber will increase the value per pop quite dramatically due to the compounding of revenue/margin over time.
- In evaluating information technology businesses such as cellular telephones, it is better to use longer value growth durations to minimize the possibility of underestimating the residual value $[(\pi_2(\overline{T})]$ and to capture the most of the growth in this industry's life cycle. This is especially important early in the industry life cycle.
- In evaluating businesses in information technology industries such as cellular telephones, time varying costs of capital (decreasing from a high initial value reflecting risks of failure, market size and share uncertainties, to a lower level representing the cost of debt financing) may be more appropriate. This is a significant departure from the traditional implementation of valuation approaches, which use a constant cost of capital. As noted by Day and Fahey [13], discount rates reflecting arbitrary (high) risk premiums can undervalue projects and result in their premature demise. One should also note that other factors such as new competitive entries can also influence the cost of capital. For example, rumors regarding the FCC allowing a third cellular firm in each geographical market may have led to a temporary decrease in value of the cellular communications business during 1987.

Conclusions and Limitations

Given the phenomenal growth or the anticipation of growth in certain information technology industries, market and business analysts are interested in assessing the relationship between market penetration and market value of a business. Focusing on the growth and market value dynamics in the cellular telephone industry, this paper has suggested an approach to link market penetration and market value of a business. When applied to the available data, the approach provided a systematic mechanism to understand the growth dynamics of the cellular phone industry and provided a model to determine the short-run and long-run going market value in this industry. The base model developed in this paper could be refined to accommodate multiple market segments. For example, the model could be modified to incorporate separate diffusion patterns, and consequently cash flows and value components, for business and residential markets. Such disaggregate models can provide further insights to aid resource allocations. For example, if the business segment is close to saturation in a specific market while the residential market is in the growth phase, one might shift resources to the latter in order to enhance value generation. In addition to industry analysts, such analyses clearly should be of interest to corporate strategists responsible for evaluating growth strategies for a business including possible merger and acquisition opportunities, strategic investments in saturated, unsaturated and untapped markets.

Despite the advantages, the proposed approach is not without shortcomings. First, although all the analyses are done at the industry level, the approach provides a benchmark market value. Even if the valuation model performs adequately in estimating the going value of a business at the industry level, adjustments are necessary if it is to be used at the firm level because of varying cost of capital and performance. In this context, however, although the approach does not provide the market value of a particular business, it does provide important indicators of comparison for such businesses. Clearly, value projections for a specific cellular service company would have to be fine-tuned to take into account regional variations in diffusion, competitive intensity in each market, its market share, and specific strengths and weaknesses relative to the competitor.

Second, in its current formulation, the valuation approach is applicable only to single-business firms. If, however, acceptable procedures can be agreed on in the value-based planning approaches to assess the value of an individual business of a multi-business firm [36], the approach suggested in this paper can be applied to assess the going market value of an individual business.

Third, the model does not take into account the fact that growth may be fueled by a decrease in prices (i.e., revenues per subscriber), which may increase the market potential. It is feasible to do "what-if" analyses based on the estimate of long-term price elasticity, however. Of course, for value to increase, the growth in subscribers will have to more than offset the decrease in prices.

Fourth, the model does not incorporate the effects of other elements of the marketing mix. For example, external influences like advertising and promotions can enhance penetration and usage, and, consequently, value.

Fifth, the model does not incorporate factors affecting customer retention, which are important during the later stage of the life cycle in service industries. Discontinuance (i.e., disadoption) and switching to competitors (i.e., churning) are beginning to grow in importance and are depressing earnings [34].

Sixth, shifts in the diffusion pattern can be influenced by technological breakthroughs such as digital PCNs, which while increasing the cost of cellular phones (equipment) to customers may result in lower monthly service fees as more lines can be packed in the same frequency band-width. One must note, however, that any model is an abstraction of reality. Its accuracy is conditional on the stability of environmental conditions.

Finally, the model development in this paper was tailored for the cellular phone industry. A question now is, how general is the approach? Can it be adapted to other industries? The answer is yes. For many information technology industries such as cable TV and long distance telecommunication, the value of businesses is evaluated on the basis of profit contribution per and potential subscribers. For such applications, the approach suggested in this paper is appropriate. Although not considered in this paper, such applications may incorporate scenarios in which the size of the market is influenced, for example, by service prices and the rate of diffusion is moderated by other marketing mix elements.

In conclusion, we believe that the proposed approach is also applicable to other industries (e.g., retailing, biomedical) where the profitability and the value of a business is linked with the actual or the anticipated penetration of the product or the business (e.g., growth of number of stores and the market value of a retailing institution). Exploration of such applications clearly will be an excellent use of market penetration models for strategic planning and management.

References

1. Alberts, W. W., and McTaggart, J. M., Value Based Strategic Investment Planning, *Interfaces* 14 (January-February), 138–151 (1984).
2. Bass, F. M., A New Product Growth Model for Consumer Durables, *Management Science* 15, 215–227 (1969).
3. Blyth, M., Friskey, E., and Rappaport, A., Implementing the Shareholder Value Approach, *Journal of Business Strategy* 6, 48–59 (1986).
4. Booz, A., and Hamilton, Inc., *Technology Management: Survey Results*, Technology Management Group, Booz, Allen, and Hamilton, New York, 1981.
5. Brand, S., *The Media Lab*, New York, Viking Penguin, 1987.
6. Bromily, P., Shareholder Value and Strategic Management: Some Caveats, in *Handbook of Business Strategy: 1986/1987 Yearbook*. William D. Guth (ed.), Warren, Gorham, and Lamont, New York, pp. 6.1–6.6, 1986.

7. Hello Anywhere—The Cellular Phone Boom Will Change the Way You Live, *Business Week*, September 21, 84–92 (1987).
8. Hello, Reality Calling—Slower Growth in Cellular Has Investors Cashing Out, *Business Week*, August 7, 22–23 (1989).
9. Not Just a Yuppie Toy Anymore, *Business Week*, February 24, 36 (1992a).
10. Craig McCaw's Very Sweet Deal, *Business Week*, November 17 (1992b).
11. *Chicago Tribune*, Money Talks in Booming Cellular Phone Industry, 5, 1 (1989).
12. Conley, P., Experience Curves as a Planning Tool, in *Corporate Strategy and Product Innovation*, (2nd ed.), Robert R. Rothberg (ed.), The Free Press, New York, pp. 132–143, 1981.
13. Day, G. S., and Fahey, L., Valuing Market Strategies, *Journal of Marketing* 52, 45–57 (1988).
14. Day, G. S., and Fahey, L., Putting Strategy into Shareholder Value Analysis, *Harvard Business Review* 68, 156–162 (1990).
15. Dhebar, A., and Oren, S. S., Optimal Dynamic Pricing for Expanding Networks, *Marketing Science* 4(4) 336–351 (1985).
16. Drucker, P. F., The Coming of New Organizations, *Harvard Business Review* 66, 45–53 (1988).
17. America's Empire Strikes Back, *Economist* 22, 61–62 (1992).
18. *Federal Tax Handbook* (1986, 1990), Paramus, NJ: Prentice-Hall Information Services.
19. Fisher, J. C., and Pry, R. H., A Simple Substitution Model for Technological Change, *Technological Forecasting and Social Change* 3, 75–88 (1971).
20. Cellular Stocks Are Down—and That May Be Just the Time to Buy, *Fortune* (June 4), 45 (1990).
21. Deals of the Year, *Fortune* (March 27), 104–110 (1992).
22. Gerstein, M. S., *The Technology Connection*, Reading, MA: Addison-Wesley, 1987.
23. Gilman, J. J., Market Penetration Rates and Their Effect on Value, *Research Management* 25, 34–39 (1982).
24. Greenberg, E. M., and Lloyd, C. M., *Pop Out: The Changing Dynamics of the Cellular Telephone Industry*, Morgan Stanley, New York, 1991.
25. Harvey, C. M., A Slow Discounting Model of Energy Conservation, *Interfaces* 6 (November-December), 47–60 (1992).
26. Heeler, R. M., and Hustad, T. P., Problems in Predicting New Product Growth for Consumer Durables, *Management Science* 26, 1007–1020 (1980).
27. House, C. H., and Price, R. L., The Return Map: Tracking Product Teams, *Harvard Business Review* 69 (January-February), 91–101 (1991).
28. Keen, P. G. W., *Competing in Time*, Ballinger Publishing Co., Cambridge, MA, 1986.
29. Kerin, R. A., Mahajan, V., and Varadarajan, P. R., *Contemporary Perspectives on Strategic Marketing Planning*, Allyn and Bacon, Boston, MA, 1990.
30. Loewenstein, G., and Prelec, D., Anomalies in Inter-Temporal Choice: Evidence and an Interpretation, *Quarterly Journal of Economics* 107 (2), 573–597 (1992).
31. Mahajan, V., and Peterson, R. A., *Models for Innovation Diffusion*, Sage, Beverly Hills, CA, 1985.
32. Mansfield, E., Technological Change and the Rate of Imitation, *Econometrica* 29, 741–766 (1961).
33. Naylor, T. H., and Tapon, F., The Capital Asset Pricing Model: An Evaluation of Its Potential as a Strategic Tool, *Management Science* 28, 1166–1173 (1982).
34. Worries Accompany Growth for Cellular Phone Industry (February 13), *New York Times* (1992).
35. Porter, M. E., and Millar, V. E., How Information Gives You Competitive Advantage, *Harvard Business Review* 63 (July-August), 149–160 (1985).
36. Rappaport, A., *Creating Shareholder Value: The New Standard for Business Performance*, The Free Press, New York, 1986.
37. Rogers, E. M., *Communication Technology*, The Free Press, New York, 1986.
38. Schnaars, S. P., *Marketing Strategy*, The Free Press, New York, 1991.
39. Srivivasan, V., and Mason, C. H., Nonlinear Least Squares Estimation of New Product Diffusion Models, *Marketing Science* 5 (2), 169–178 (1986).
40. Srivastava, R. K., Valuation of Marketing Growth Opportunities, in *Concurrent Life Cycle Management*, F. Y. Phillips (ed.), The IC² Institute, The University of Texas at Austin, pp. 115–130 (1991).
41. Thaler, R., Some Empirical Evidence of Dynamic Inconsistency, *Economic Letters* 8(3), 201–207 (1981).
42. U.S. Department of Commerce, *A Competitive Assessment of the US Cellular Radio Telephone Industry*, (June) (1988).
43. Wiseman, C., *Strategy and Computers: Information Systems as Competitive Weapons*, Dow Jones-Irwin, Homewood, IL, 1985.
44. Woo, C., An Empirical Test of Value-Based Planning Models and Implications, *Management Science* 30, 1031–1050 (1984).

Received 15 October 1994; accepted 7 January 1995